NANO VISION
An International Open Free Access, Peer Reviewed Research Journal
www.compmath-journal.org

ISSN 2231-2579 (Print)
ISSN 2319-7633 (Online)
Abbr: Nano Vision.
2013, Vol.3(3): Pg.169-174

Biosynthesis, Characterization and Application of Titanium Dioxide Nanoparticles

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Presented in First National Conference on Thin Film Science and Nano Technology (FIRST-NCTFSANT-2013) September 2-3, 2013, Rajah Serfoji Govt. College, Thanjavur, T.N.(India).

ABSTRACT

Green nanotechnology is generating interest of researchers toward eco-friendly biosynthesis of nanoparticles. In the present work, Titanium dioxide nanoparticles were synthesized by using Aloe vera gel extracts. The sample was characterized by UV-Visible spectroscopy, X-ray diffraction (XRD), Fourier Transform Infrared spectroscopy (FTIR), UV- DRS spectroscopy (UV-Vis DRS) and Atomic Force Microscopy (AFM). Rhodamine B dye was used as a model pollutant to study its photocatalytic activity under visible light irradiation.

Keywords: Biosynthesis, Aloe vera gel, Nanoparticles, Titanium dioxide.

1. INTRODUCTION

Transition metal oxides with nanostructure have a high specific surface area and a high fraction of surface atoms. Because of the unique physicochemical characteristics of nanoparticles, including catalytic activity, optical properties, electronic properties, antibacterial properties, and magnetic properties they are gaining the interest of scientist for their novel methods of synthesis of metal oxide nanoparticles.

Nanoparticles can be synthesized using various approaches including chemical, physical, and biological methods. Although chemical method of synthesis requires short period of time for synthesis of large quantity of nanoparticles, this method requires capping agents for size stabilization of the nanoparticles. Chemicals used for nanoparticles synthesis and stabilization are toxic and lead to non-ecofriendly byproducts. The need for environmental non-toxic synthetic protocols for nanoparticles synthesis leads to the developing interest in biological approaches which are free from the use of toxic chemicals as byproducts. Thus, there is an increasing demand for

''green nanotechnology''[1].

Titanium dioxide (TiO_2) is a nontoxic material and has been applied in environmental treatments such as water and air purification, water disinfection and sterilization because of its unique properties such as strong photocatalytic activity and chemical stability. The most widely accepted mechanism is the migration of valence electron to conduction band and formation of hole-electron pairs. These hole-electron pairs react with adsorbed molecules at semiconductor surface, resulting in degradation of adsorbates. An only drawback is it has wide band gap energies (3.2eV) and its activity in UV region. The formation of nanoparticles which exhibit the activity of TiO_2 in the visible region. Preparation of nanoparticles using green technologies is advantageous over chemical agents due to their less environmental consequences. Reports are available for the synthesis of metal nanoparticles using environmentally benign materials like plant extracts, bacteria, fungi and enzymes[2-11]. Few reports are available for the Biosynthesis of metal oxide nanoparticles[12-14]. In the biosynthesis method, extracts from plant may act as both reducing and capping agents in synthesis of nanoparticles.

Aloe Vera is known to have 75 nutrients that are 20 minerals, 20 amino acids, 12 vitamins and water makes use large part of the medicinal industry. Numerous scientific studies on Aloe Vera are demonstrating its analgesic, anti-inflammatory, wound healing, immune modulating and anti-tumor activities as well as antiviral, anti-bacterial, and antifungal properties. The AloeVera extract play a key role in the formation of the gold nanotriangles with the shape-directing effects[15]. Aloe vera acts as a reducing and stabilizing agents for synthesis of TiO_2 nanoparticles.

In this paper, we report to Biosynthesis of TiO_2 nanoparticles by using Aloe vera extract and characterized by XRD, UV-Visible and IR spectroscopic techniques. Photocatalytic efficiency was performed for Rhodamine B (RhB) dye and its kinetic behaviour was also studied.

2. MATERIALS AND METHODS

2.1. Materials

Commercially available TiO_2 and Rhodamine B were used. All the solutions were prepared by using double distilled water. The Aloe vera leaves were collected from local agricultural fields in Tamilnadu.

2.2. Synthesis

The Aloe vera extract was prepared by taking inner gel portion of Aloe vera leaves were boiled for 10 min with de-ionized water. The filtered broth extract was kept at 10 ^{o}C for further experiments.

For synthesis of TiO_2 NP's, 100 mL of $TiO(OH)_2$ (5mM) and 20mL of the aqueous extract of Aloe vera were stirred for 24 h continuously. The formation of nanoparticles is confirmed by changing the colour to light green. The obtained precipitate was dried in a hot air oven at 120^{o}C for 1 h. During drying, complete conversion of $TiO(OH)_2$ into TiO_2 took place.

2.3. Characterization

Particle size of TiO_2 NP's was studied by Atomic Force Microscopy

technique. The phase composition of the prepared sample was studied using powder XRD technique. Fourier transform infrared spectroscopy (FTIR) was used to determine the functional group present in the nanoparticles. UV–visible spectrophotometer was employed for absorbance measurements of samples.

2.4. Removal of reactive dyes

For Photocatalytic study, 5 mg/L concentration RhB was used as the model pollutant. At given irradiation time interval, 4 ml of the samples were taken and analyzed by UV–Visible spectrometer. The decolourization behaviour and kinetics were studied. Degradation rate was calculated using the following equation

$$\text{Degradation rate (\%)} = \left[\frac{Co-C}{Co}\right] \times 100$$

Where, C_0 is the initial concentration of dye and C is the concentration of pollutant at time t.

Photocatalytic reactions kinetics on photocatalyst can be expressed by the Langmuir–Hinshelwood (L–H) model.

$\ln(C_o/C) = k_{app}\, t$

where k_{app} is the apparent pseudo first order reaction rate constant and t is the reaction time. A plot of $\ln (C_o/C)$ versus t will yield a slope of k_{app}.

3. RESULTS AND DISCUSSION

3.1. UV-Visible Spectroscopy

The diffused reflectance spectrum of TiO_2 nanoparticle was obtained in terms of F(R) values by the application of Kubelka-Munk algorithm. The band gap was found to be 3.1eV (Fig.1).

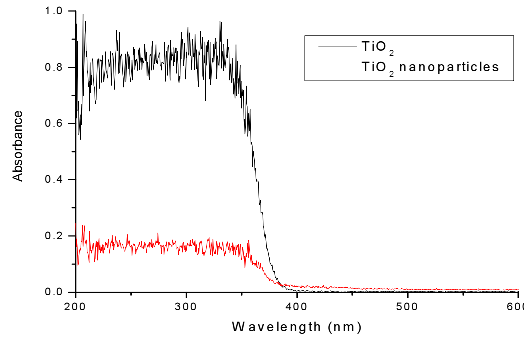

Fig.1. UV-DRS of TiO_2 nanoparticles

3.2. XRD

The XRD pattern of synthesized TiO_2 nanoparticle shows major peak appeared with 2θ value of 25.2°, 47.9° and 55.0° corresponds to (101), (200) and (211) planes of tetragonal geometry of TiO_2 NP's, which is in agreement with the JCPDS file no. 89-4203 and the crystal structure is predominantly anatase dominant. The average particle size of composite was calculated by scherrer's equation and the size was about 11nm in Fig.2.

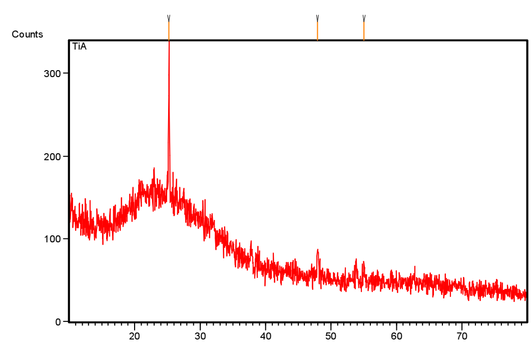

Fig.2.XRD pattern of TiO_2 nanoparticles

3.3. FT-IR Spectroscopy

In FT-IR spectrum the peak observed at 3396 cm^{-1} due to stretching vibration of hydroxyl group and the peak appeared at 1608 cm^{-1} due to amino groups present in alcohols, phenols and amines in aloe vera extract participating in nanoparticles synthesis. The peak observed around 1000cm^{-1} confirmed the existence of metal oxide (Fig.3).

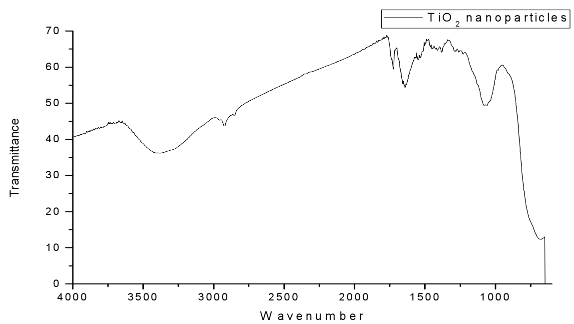

Fig.3.FTIR spectrum of TiO_2 nanoparticles.

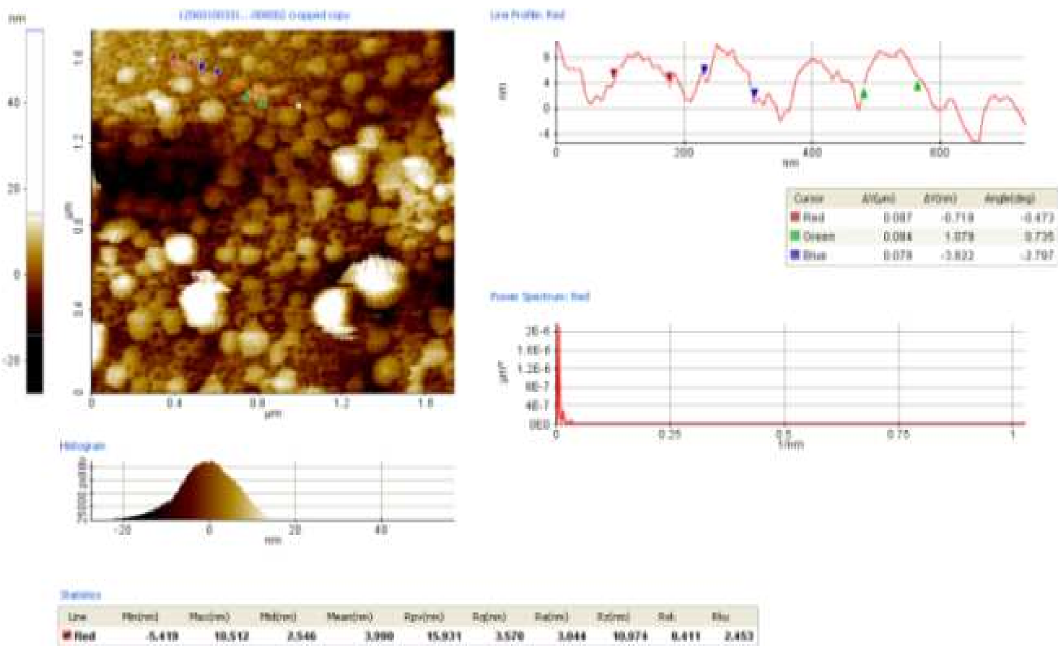

Fig.4. Atomic Force Microscopy image of TiO_2 nanoparticles

3.4. Particle size Analysis

Particle size was analysed by Atomic Microscopy image in two dimensional view (Fig.4). The size of the synthesized particles lies between 80-90 nm.

3.5. Photocatalytic activity

The Photocatalytic experiment was carried out for Rhodamine B dye and the concentration used for this study was 5 mg/L. The catalyst TiO_2 and TiO_2 NP's were used for this study in the amount of 0.3 g/L. The Photocatalytic decolourization results by the rapid cleavage of chromophores, which is responsible for the colour of the dyes. The percentage of decolourization was about 41% for TiO_2 NP's and 24% for TiO_2.

A plot of ln (C_o/C) versus irradiation time and absorbance spectra of RhB under visible light irradiation was presented in (Fig.5.). The apparent rate constants k_{app} can be approximated as pseudo-first-order kinetics. The Photocatalytic activity shows high percentage of decolourization for TiO_2 NP's as compared to TiO_2.

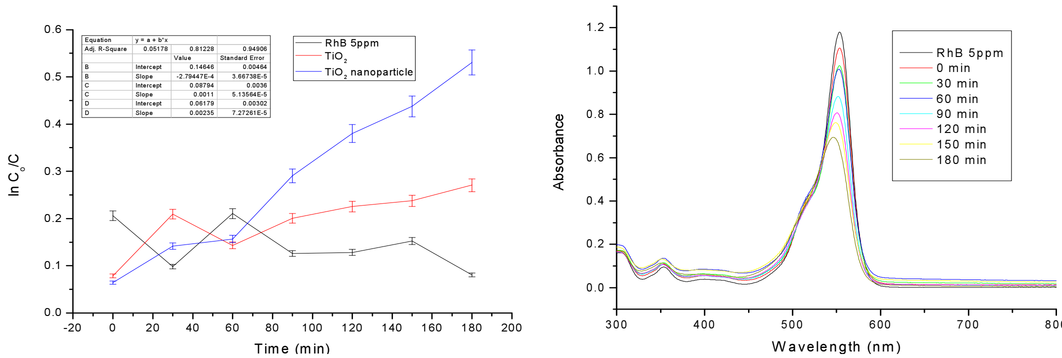

Fig.5.a. Plot of ln (C_o/C) Vs irradiation time b. Time dependent absorption spectra of RhB dye under visible light irradiation.

CONCLUSION

TiO_2 NP's was synthesized by using Aloe vera gel extract which develop a simple, cheap and eco-friendly method. The XRD confirms the crystal structure of TiO_2 NP's is predominanatly anatase phase. Microscopic image confirms the particles are in nanometer size. The Photocatalytic activity was tested for Rhodamine B dye and the % of decolourization was effective for TiO_2 NP's as compared to TiO_2.

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